A statistical study of stability indexes as convective weather predictors in Lombardia

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I. INTRODUCTION

Forecasting thunderstorm occurrence is still a difficult task for both NWP models and weather forecasters due to the small spatial and temporal scales involved. The low predictability of convective phenomena still justifies the operational practise of using empirically developed stability indexes to evaluate the atmospheric potential for storm development. The value of such indexes is in their capacity to summarise characteristics of the convective environment in a single number which can be easily computed from operational sounding data and used for very short range forecasts of thunderstorm occurrence, generally associated to a threshold.

To be used effectively indexes and reference thresholds should be verified and tuned using local storm climatology. This is even more important when, as in northern Italy, morphological characteristics that contribute to initiation and development of convective phenomena are very different from those of the areas for which indexes have been developed, and for which the threshold have been tested.

In latest years different studies have been performed to investigate and/or adapt stability indexes to European regions (among others: Hacklander and Van Delden, 2003; Huntrieser et al., 1997; Dalla Fontana, 2008; Manzato, 2003). This work follows their tracks applying some of the same methods to the study of convection in Lombardia. Thanks to the length and completeness of the data set used, is has been possible to stratify cases with respect to time of day, location, intensity and synoptic configuration, with an emphasis on sampling of phenomena and on statistical significance of results.

II. PRESENTATION OF RESEARCH

A study of thunderstorm occurrence in the $300km \times 300km$ area including Lombardia (Northern Italy) was performed analysing cloud-to-ground lightnings detected by the CESI-SIRF system (http://www.fulmini.it/) over a ten year period (1999-2008). The presence of at least one lightning strike in each 12 hour period between 00-12UTC and 12-00UTC was used to discriminate between thundery mornings/afternoons (active case) and stable mornings/ afternoons. No other observation of convective activity has been used, as none of those available to the SMR and used by the authors cited above could cover the same ten year observation period with sampling characteristics comparable to the lightning detection system (high spatial and temporal resolution, high precision of reports, ease of data processing). As expected convection is significant only in summer months (Fig. 1); hence only the period from May to September has been considered for the analysis of stability indexes.

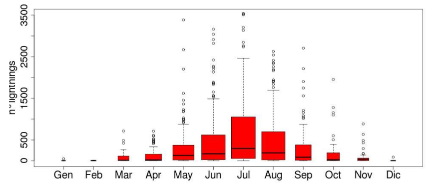

FIG. 1: Monthly distribution of lightning number in each convective event of the 00-12UTC period.

Nine common indexes (K index, Total Totals index, Lifted index, Showalter index, CAPE, CIN, SWEAT, U index, Potential Instability index) were computed from Milano Linate 00 UTC and 12 UTC soundings. The distribution of stability indexes' values was studied in active and non-active mornings/afternoons in order to evaluate wich indexes are best suited for identifying the potential for convective activity in the area. Optimal threshold values for thunderstorm occurrence were estimated for all of the stability indexes under study (maximising True Skill Statistic and ROC curves), for 00 UTC and 12 UTC soundings separately. The uncertainty in the estimated optimal threshold values and in the forecasting skill of stability index above the threshold was evaluated by re-sampling techniques (Fig. 2). The technique was also used to rule out the possibility of difference in results being due to changes in the data set (overall number of cases, proportion of YES/NO cases).

To study the characteristics of widespread and/or intense convection, and to discriminate it from isolated or weak thunderstorm cases, the region was divided in a $29km \times 29km$ grid (64 cells), and the occurrence and number of strikes in each grid cell was examined. The number of grid cells with at least one lightning and the maximum number of lightnings per cell were used to identify days of severe/widespread convection, and to study the difference in the distribution of stability indexes' values in this case. TSS and ROC curves were used to identify optimal thresholds for severe convection, as in the preceding analysis of all active cases, and difference in the results was checked for statistical significance by re-sampling the data and changing the proportion of events. The same analysis were also performed for thunderstorms occurring in different areas of Lombardia: north, south and in a $50km$ square centered on Linate sounding (to check for representativity dependence). Lastly, thunderstorms occurring in different synoptic configurations were analysed by subjectively classifying flow type in four categories (trough, ridge, westerly flow and weak flow, following Cacciamani et al., 1995).

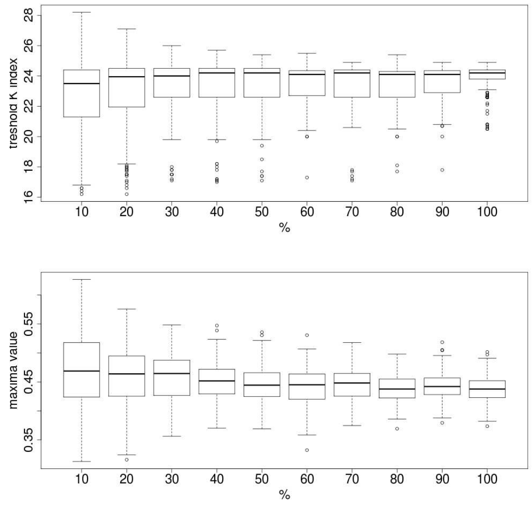

FIG. 2: Distribution of TSS maximum position (above) and value (below) for 1000 resamlpings of the data vs. fraction of total.

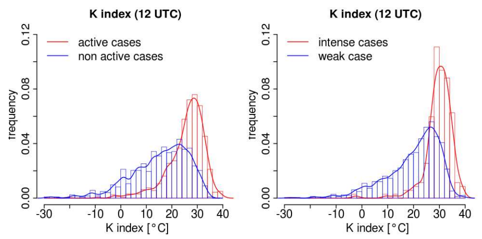

FIG. 3: Left: distribution of KI values in active/non active cases (red/blue). Right: distribution of KI values in intense/ weak or absent convection (red/blue).

Statistical significance of the difference in the results was considered.

III. RESULTS AND CONCLUSIONS

The highest frequency of thundery days and the most severe/widespread convection was found to be in July, as expected (see Fig. 1). The characteristics of convection in the two periods (00-12 UTC and 12-00 UTC) as detected by lightning strikes was found to be in line with findings by other authors for the same area using other observation methods for convective activity, as hail or heavy rain observation, SYNOP reports, damage reports, radar echos (Cacciamani et al., 1995). Thunderstorms are more frequent in the northern area of Lombardia and in the afternoons. Early morning convection and thunderstorms in the low lying southern areas are less frequent in general, and their peak frequency is later on in the season (August-September vs. June-July).

Of the stability indexes considered, TT index calculated on 12UTC soundings has the highest skill in forecasting occurrence of thunderstorms in the following 12 hours in Lombardia ($TSS = 0.51$); in general forecasting skill is higher for the 12-00UTC period. Good skill was found also for Showalter and K index (0.48 and 0.45 respectively). CAPE, CIN and SWEAT are, as expected, more difficult to interpret. Thresholds are comparable to those in literature, but optimality seems to be gained for lower threshold values. For some indexes (K, LI, CAPE) the threshold differences in the 12 UTC and 00 UTC soundings are also significant. In general *parcel indexes* and CAPE exhibit higher skill in the northern, hilly, area of the region, whereas TT, K, U, PI are perform better when forecasting convection in the southern area.

For intense/widespread convection cases, K index increases its forecasting skill and its optimal threshold values significantly (TSS from 0.45 to 0.54 and threshold from 24.0 C to 27.0 C, see figure 3); also CAPE's and LI's optimal thresholds move towards more unstable values, and the differences are significant even taking into account the reduced number of intense/widespread convection cases with respect to active cases (804 active cases, 175 intense/widespread cases on a total of 1418).

The analysis of instability indexes for thunderstorms occurring in different synoptic configurations shows a significantly improved forecasting skill of some indexes indexes in stable (ridge) or weakly unstable (westerly flow) configurations (CAPE, LI, PI, SH), with optimal threshold moving towards more unstable values. U and SWEAT indexes, which were not found to have good forecasting skill in general, appear instead to be useful in forecasting thunderstorm occurrence in the case of westerly flow.

This work has been performed with the final aim of giving a set of quantitatively verified forecasting thresholds for the stability indexes most used in operational activity at Lombardia's weather service. To the authors' best knowledge, this is the first systematic study on stability indexes in Lombardia, and the first making the effort to give quantitative indications on their use in forecasting thunderstorms for different areas/intensity/configurations, with indication on significance and uncertainty of results.

IV. REFERENCES

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